AMENDMENT TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

LISTING OF CLAIMS

1 – 120 (cancelled)

121. (new) A method for mapping a current pose P of an image boundary in a digital image into a more accurate pose P' of the image boundary, the image boundary having N image boundary points, the method comprising:

solving a plurality of simultaneous equations, the plurality including an equation for each of a respective plurality of image boundary points of the image boundary, so as to provide a coordinate transform; and

applying the coordinate transform to each of the image boundary points that maps the current pose P of the image boundary into a more accurate pose P' of the image boundary, the coordinate transform being of the form P' = CP + t, where C is a matrix, and t is a translation vector.

122. (new) The method of claim 121, wherein the coordinate transform is a six degree-of-freedom coordinate transform.

123. (new) The method of claim 121, wherein each image boundary point includes a position.

124. (new) The method of claim 121, wherein each image boundary point includes a position and a direction.

125. (new) The method of claim 121, wherein the plurality of simultaneous equations is solved repeatedly, using the more accurate pose P' as a starting pose P with each repetition.

126. (new) The method of claim 121, wherein more than twelve equations are solved simultaneously.

127. (new) The method of claim 121, wherein solving a plurality of simultaneous equations includes:

using an error minimization method to minimize a sum of a plurality of error terms, each error term corresponding to an image boundary point.

128. (new) The method of claim 121, wherein solving a plurality of simultaneous equations includes:

using a least-squares method.

129. (new) The method of claim 127, wherein an error term is equal to a magnitude of a component of a vector in the direction of a displacement vector representing a minimum distance between an image boundary point and a pattern boundary, minus a magnitude of the displacement vector.

130. (new) The method of claim 128, wherein the least squares method includes an error term for each image boundary point, and a weight value is determined for each image boundary point.

131. (new) The method of claim 130, wherein a total error is computed by summing, over a plurality of image boundary points, the product of the square of an associated error term and an associated weight value.

132. (new) The method of claim 131, wherein each error term includes a contribution from each degree of freedom.

133. (new) The method of claim 128, wherein using the least squares method involves no more than four degrees of freedom.

134. (new) The method of claim 133, wherein the four degrees of freedom are selected from: x-translation, y-translation, orientation, and size.

135. (new) The method of claim 134, wherein the degrees of freedom selected are determined by at least one parameter.

136. (new) The method of claim 134, wherein the orientation degree of freedom is defined by an orthonormal real-world coordinate system.

137. (new) A method for mapping a current pose P of an image boundary in a digital image into a more accurate pose P' of the image boundary, the image boundary having N image boundary points, the method comprising:

solving a plurality of simultaneous equations so as to provide a coordinate transform, the plurality including an equation for each of a respective plurality of image boundary points of the image boundary, the plurality being simultaneously solved using a least-squares method to minimize a linear sum of a plurality of squared error terms, each error term corresponding to an image boundary point; and

applying the coordinate transform to each of the image boundary points that maps the current pose P of the image boundary into a more accurate pose P' of the image boundary, the coordinate transform being of the form P' = CP + t, where C is a matrix, and t is a translation vector.

138. (new) The method of claim 137, wherein the coordinate transform is a six degree-of-freedom coordinate transform.

139. (new) The method of claim 137, wherein each image boundary point includes a position.

140. (new) The method of claim 137, wherein each image boundary point includes a position and a direction.

141. (new) The method of claim 137, wherein the plurality of simultaneous equations is solved repeatedly, using the more accurate pose P' as a starting pose P with each repetition.

142. (new) The method of claim 137, wherein more than twelve equations are solved simultaneously.

143. (new) The method of claim 137, wherein each error term is equal to a magnitude of a component of a vector in the direction of a displacement vector representing a minimum distance between an image boundary

point and a pattern boundary, minus a magnitude of the displacement vector.

144. (new) The method of claim 137, wherein the linear sum includes a weight coefficient for each squared error term.

145. (new) The method of claim 144, wherein a total error is computed by summing, over a plurality of image boundary points, the product of the square of an associated error term and an associated weight value.

146. (new) The method of claim 145, wherein each error term includes a contribution from each degree of freedom.

147. (new) The method of claim 137, wherein using the least squares method involves no more than four degrees of freedom.

148. (new) The method of claim 147, wherein the four degrees of freedom are selected from: x-translation, y-translation, orientation, and size.

149. (new) The method of claim 148, wherein the degrees of freedom selected are determined by at least one parameter.

150. (new) The method of claim 148, wherein the orientation degree of freedom is defined by an orthonormal real-world coordinate system.

151. (new) In a geometric pattern matching apparatus for refining a starting pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the geometric pattern matching apparatus having (1) a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points of a pattern boundary, and a vector-valued function of position within a region that includes the pattern boundary points, and (2) a feature detector adapted to detect in the run-time image a plurality of image boundary points, a method for mapping a current pose P of an image boundary in the run-time image into a more accurate pose P' of the image boundary, the image boundary having a plurality of image boundary points, the method comprising:

solving a plurality of simultaneous equations, the plurality including an equation for each of a respective plurality of image boundary points of the image boundary, so as to provide a coordinate transform; and

applying the coordinate transform to each of the image boundary points that maps the current pose P of the image boundary into a more accurate pose P' of the image boundary.

152. (new) The method of claim 151, wherein the coordinate transform is a six degree-of-freedom coordinate transform.

153. (new) The method of claim 151, wherein the coordinate transform is of the form

$P' = CP + t$, where C is a matrix, and t is a translation vector.

154. (new) The method of claim 151, wherein each image boundary point includes a position and a direction.

155. (new) The method of claim 151, wherein the plurality of simultaneous equations is solved repeatedly, using the more accurate pose P' as a starting pose P with each repetition.

156. (new) The method of claim 151, wherein more than twelve equations are solved simultaneously.

157. (new) The method of claim 151, wherein solving a plurality of simultaneous equations includes:

using an error minimization method to minimize a sum of a plurality of error terms, each error term corresponding to an image boundary point.

158. (new) The method of claim 151, wherein solving a plurality of simultaneous equations includes:

using a least-squares method.

159. (new) The method of claim 157, wherein an error term is equal to a magnitude of a component of a vector in the direction of a displacement vector representing a minimum distance between an image boundary point and a pattern boundary, minus a magnitude of the displacement vector.

160. (new) The method of claim 158, wherein the least squares method includes an error term for each image boundary point, and a weight value is determined for each image boundary point.

161. (new) The method of claim 160, wherein a total error is computed by summing, over a plurality of image boundary points, the product of the square of an associated error term and an associated weight value.

162. (new) The method of claim 161, wherein each error term includes a contribution from each degree of freedom.

163. (new) The method of claim 158, wherein using the least squares method involves no more than four degrees of freedom.

164. (new) The method of claim 163, wherein the four degrees of freedom are selected from: x-translation, y-translation, orientation, and size.

165. (new) The method of claim 164, wherein the degrees of freedom selected are determined by at least one parameter.

166. (new) The method of claim 164, wherein the orientation degree of freedom is defined by an orthonormal real-world coordinate system.

167. (new) A method for mapping a current pose P of an image boundary in a digital image into a more accurate pose P' of the image boundary, the image boundary having N image boundary points, the method comprising:

solving a plurality of simultaneous equations so as to provide a coordinate transform, the plurality including an equation for each of a respective plurality of image boundary points of the image boundary, the plurality being solved by using an error minimization method to minimize a sum of a plurality of error terms, each error term corresponding to an image boundary point; each error term including a magnitude of a component of a vector in the direction of a displacement

vector representing a minimum distance between an image boundary point and a pattern boundary, minus a magnitude of the displacement vector; and

applying the coordinate transform to each of the image boundary points that maps the current pose P of the image boundary into a more accurate pose P' of the image boundary.

168. (new) The method of claim 167, wherein the coordinate transform is of the form

$P' = CP + t$, where C is a matrix, and t is a translation vector.

169. (new) The method of claim 167, wherein the coordinate transform is a six degree-of-freedom coordinate transform.

170. (new) The method of claim 167, wherein each image boundary point includes a position and a direction.

171. (new) The method of claim 167, wherein the plurality of simultaneous equations is solved repeatedly, using the more accurate pose P' as a starting pose P with each repetition.

172. (new) The method of claim 167, wherein more than twelve equations are solved simultaneously.

173. (new) The method of claim 167, wherein solving a plurality of simultaneous equations includes:

using a least-squares method.

174. (new) The method of claim 167, wherein a weight value is determined for each image boundary point.

175. (new) The method of claim 174, wherein a total error is computed by summing, over a plurality of image boundary points, the product of an error term and an associated weight value.

176. (new) The method of claim 175, wherein each error term includes a contribution from each degree of freedom.

177. (new) The method of claim 167, wherein using the error minimization method involves no more than four degrees of freedom.

178. (new) The method of claim 177, wherein the four degrees of freedom are selected from: x-translation, y-translation, orientation, and size.

179. (new) The method of claim 178, wherein the degrees of freedom selected are determined by at least one parameter.

180. (new) The method of claim 178, wherein the orientation degree of freedom is defined by an orthonormal real-world coordinate system.